Docket No. 043290.P5113

United States Patent Application for

A METHOD FOR USING ENCODED SPREADING CODES

TO ACHIEVE HIGH BIT DENSITIES IN A DIRECT-SEQUENCE

SPREAD SPECTRUM COMMUNICATION SYSTEM

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<u>FIELD OF THE INVENTION</u>

The present invention relates to the field of data communications. More particularly the invention describes a method of using encoded spreading codes to achieve high bit

5 densities in direct sequence spread spectrum communication systems.

<u>BACKGROUND OF THE INVENTION</u>

Direct Sequence Spread Spectrum (DSSS) techniques rely on the use of pseudo-noise carriers, also called spreading codes, spreading sequences, code sequences and chip

10 sequences, and a transmission bandwidth which is much wider than the minimum required to transmit the information. The transmitter spreads the information by modulating the information with a pseudo-noise spreading sequence. At the receiver, the information is despread to recover the base information. This despreading is accomplished by correlating the received, spread-modulated, signal with the spreading sequence used for the transmission.

15 DSSS is sometimes referred to by the shorthand name "direct spread."

The modulating signal, such as a pseudo-random spreading code signal, possesses a chip rate (analogous to carrier frequency) which is much larger than the data rate of the information signal. This characteristic is required for efficient spreading. Each state of the pseudo-random spreading sequence is referred to as a chip. The spreading sequence (chip

20 sequence) directly modulates each bit of the information signal, hence the name direct spread. Pseudo-randomness of the spreading signal is required in order to recover the original information signal. Since the spreading sequence is deterministic, it can be exactly duplicated

1

at the receiver in order to extract the information signal. If it were truly random, extraction of the information signal via correlation receiver would not be possible.

The spreading operation causes the signal power to be depleted uniformly across the spread bandwidth. Thus, the spread spectrum signal will appear buried in noise to any receiver

5 without the despreading signal. Consequently, it is not only difficult to jam, but is also difficult to detect its presence in any bandwidth. Any undesired signal picked up during transmission is spread by the receiver in the same way that the transmitter spread the desired signal originally. In other words, the receiver spreads undesired signals picked up during transmission, while simultaneously despreading, or demodulating, the desired information

10 signal. Processing gain is the term used to express this interference suppression in the overall transmit/receive operation. When viewed as a transmit/receive operation, the desired signal is spread-modulated twice, giving back the original signal, while in-band interference is spread-modulated once, and thereby depleted across the full spread bandwidth.

15

SUMMARY OF THE INVENTION

A method for achieving high bit densities in a direct-sequence spread spectrum communication system by using encoded spreading codes. First, an encoded pseudo-noise

20 code is created. This encoded pseudo-noise code is then used to spread a first signal by modulating the first signal with the encoded pseudo-noise code.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is illustrated by way of example and not limitation in the figures of the accompanying drawings, in which like references indicate similar elements and in which:

Figure 1(a) is a diagram showing a signal being spread.

Figure 1(b) is a diagram showing a spread signal with interference being demodulated into the original signal and noise.

Figure 2(a) is an exemplary prior art method of spreading signals.

Figure 2(b) is an exemplary method of spreading signals using an encoded pseudo-noise code.

Figure 3 is a block diagram of receiving and decoding the spread modulated signal of figure 2.

Figure 4 is a block diagram of a multiple user system implementing the encoded spreading method of Figures 2 and 3.

DETAILED DESCRIPTION OF THE INVENTION

The disclosed method utilizes the oversampled nature of spreading codes in direct

sequence spread spectrum techniques to encode the spreading codes. The encoding is

accomplished by altering a single chip (a single state) within the spreading sequence. This

5   conveys an additional 'n-1' bits per symbol (length of spreading sequence), where 'n' is the

log-base-2 of the spreading code length. Information capacity is greatly increased over the

conventional direct-sequence spread spectrum techniques, such as the one described above,

with virtually no change in transmit power. In addition, the implementation is relatively

simple and produces only a slight variation in the correlation properties of theoretically ideal

10   correlation.

The excess bandwidth inherent in spread spectrum modulation can be exploited to

increase information capacity, without sacrificing the benefits of the spread spectrum

techniques. The over-sampled nature of the spreading code allows additional information to

be embedded within. Because each spreading code symbol is represented by a large number of

15   chips, a change to one chip of the length 'n' spreading code has minimal impact on the overall

efficacy of the underlying spread spectrum technique, while significantly increasing the

information capacity over conventional direct-sequence spread spectrum techniques.

Figure 1(a) shows an example of what occurs to a signal when it is spread. Signal 100

is spread using a spreading sequence (not shown) into signal 101. As can be seen, the

20   amplitude of the signal is decreased, while its bandwidth is expanded. By reducing the

amplitude, the signal will appear indistinguishable from noise, and can only be recovered by a

receiver which processes the correct spreading sequence. Figure 1(b) shows the spread signal

4

101 and an interference signal 102 which has been picked up during transmission. When the spread modulated signal 101 is demodulated by using the original spreading sequence (not shown), the original signal 100 is recovered and the interference signal 102 is spread into signal 103, thereby being reduced to noise.

5   Figure 2(a) is a diagram of an exemplary prior art method of spreading a signal. An information signal 210 is modulated, using known methods, by a pseudo-noise code 211. For each '1' in the information signal, the pseudo-noise code 211 is transmitted. Whereas for each '0' in the information signal, the inverse of the pseudo-noise code 211 is transmitted. Thus, through such modulation, the signal is spread out for transmission into the transmitted signal

10   212. For example, if the information signal 210 consists of the bits '101' and the pseudo-noise code 211 is '01011010' then the transmitted signal 212 is '01011010 10100101 01011010.' This transmitted signal is created by '1' corresponding to the pseudo-noise code 211 ('010110101') and '0' corresponding to the inverse of the pseudo-noise code ('10100101').

          Figure 2(b) is a diagram of an exemplary method of spreading a signal using an

15   encoded pseudo-noise code. As described above, the information signal 210 is again modulated by a spreading signal to create a transmitted signal 214. However, in this case, instead of using a pseudo-noise code, an encoded pseudo-noise code is used. By using an encoded pseudo-noise code, multiple bits of information can be transmitted per each pseudo-noise code instead of a single bit, as described above. The encoded pseudo-noise code is

20   created by inverting one bit in a pseudo-noise code wherein the inverted bit of the pseudo-noise code corresponds to the value of the information signal being sent. As a trivial example, if two bits of information are to be sent per each pseudo-noise code, a four bit pseudo-noise

code is required because two bits of information have a value ranging from zero to three. If the value of the information bits is 3 (the bits are '11'), then the third bit of the pseudo noise code is inverted, where the bits are numbered zero through three. The encoding operation provided by inversion of one bit of a pseudo-noise code results in high bit densities of

5   transmitted data while still containing high correlation. In any set of non-trivial length spreading codes, inversion of one bit will have an insignificant effect on the correlation properties, therefore, even inverting one bit will still result in high correlation for these non-trivial code lengths. For example, in Figure 2(b), the same trivial information signal 210 ('101') and pseudo-noise code 211 ('01011010') of Figure 2(a) is used. In this case, since a

10   binary '101' equals a numeric 5, the encoded pseudo-noise code is '01111010,' where the encoded pseudo-noise code is pseudo-noise code with the fifth bit inverted. Thus, the encoded pseudo-noise code corresponds to '101' and the transmitted signal is therefore the encoded pseudo-noise code of '01111010.'

Figure 3 shows the receipt and decoding of the transmitted signal. When the

15   transmitted signal 214 from figure 2(b) is received, it is compared to the correlators for that pseudo-noise code 318. Each correlator is the pseudo-noise code 318 with one bit inverted where the location of the inverted bit indicates the value of the signal. The transmitted signal may be compared to the correlators simultaneously. When a match is found then the value corresponding to the correlator (which corresponds to the location in which and inverted bit

20   was found) is read. This value is the value of the original signal. In this manner, the signal is demodulated, or despread. Using the example of the transmitted signal '01111010,' when it is compared with each correlator, it is found that it corresponds to correlator 315, where

6

correlator 315 is pseudo-noise code 318 with the fifth bit inverted. Therefore the decoded

signal 320 is equal to the numeric value '5' and in a binary signal is '101.'

In the example described above, an eight bit pseudo-noise code was used to transmit

three bits of information. Of course, other values could be used. For example, to transmit 2

5   bits of information at a time, a four bit pseudo-noise code is required. Similarly, to transmit 4

bits of information, a 16-bit pseudo-noise code is required, to transmit 5 bits of information, a

32-bit pseudo-noise code is required, to transmit 6 bits of information, a 64-bit pseudo-noise

code is required, etc.

Figure 4 shows a block diagram implementing the above modulating and

10   demodulating process in a multiple-user arena. The transmitting device 400 contains a table of

orthogonal spreading codes 410, e.g. Walsh Codes. The use of orthogonal spreading codes

allows each user to be assigned a different spreading code without any two users overlapping.

For example, the first spreading code (code 1) 411, corresponds to user 1 450, the second

spreading code (code 2) 412, corresponds to user 2 460, etc. down to code n 415 and user n

15   490. When a signal is to be sent, the pseudo noise code for the desired user 420 is chosen. The

information signal 430 is then spread using encoded pseudo-noise codes 440 as described

above. This signal is then transmitted. The transmitted signal is then received by the multiple

users. Each user (450, 460) has correlators (451, 461) corresponding to the pseudo-noise code

assigned to that user (411, 412) with one bit inverted corresponding the value of the signal, as

20   described above. If the signal is intended for the user, then the correlators will find a match

and the signal will be despread, or demodulated.

7